REMARKS

Applicants have thoroughly considered the Examiner's remarks and respectfully request reconsideration of the application as amended. Claim 2 has been amended by this Amendment A. Thus, upon entry of this amendment, claims 1- 10 will be pending. Attached hereto is a marked-up version of the changes made to the claims by the current amendment. The attached page is captioned "Version With Markings To Show Changes Made."

Claims 1, 2 and 9 stand rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicants regard as the invention. Specifically, the Examiner found that the claims were rendered indefinite by the term "predetermined." Applicants respectfully disagree. The term "predetermined" provides sufficient clarity and precision when read in light of the application to apprise one skilled in the art of the scope of the claims at issue. For example, the present application illustrates an exemplary velocity profile in Fig. 4 and describes how such a profile defines a target pull rate. The application further references U.S. Patent No. 5,919,302, which describes how to determine an optimum pull rate profile for improved crystalline structure. (See application, page 14, lines 10-21; Fig. 4). Moreover, the present application explains how the velocity profile is stored in a memory, for example. (See application, page 14, lines 22-24). Thus, the application clearly sets forth at least one way in which the velocity profile is predetermined and used according to the present invention.

Therefore, one of ordinary skill in the art is reasonably apprised of the scope of claims 1 and 9 with respect to the term "predetermined." For this reason, applicants submit that these claims comply with the requirements of 35 U.S.C. § 112.

With respect to claim 2, applicants have removed the language to which the Examiner objected. Accordingly, claim 2 is believed to comply with § 112.

Claims 1-6 and 9-10 stand rejected under 35 U.S.C. 103(a) as being unpatentable over Cope, U.S. Patent No. 3,761,692. The Examiner admits that the Cope reference fails to show every feature of the claimed invention. He asserts, however, that the Cope system differs from the present invention only in that PID control is also performed by Cope on the pull rate. To

remedy this deficiency, the Examiner notes that "the pull rate adjustments reads on the application's substantially following a set velocity profile because the average pull rate profile of Cope is determined by the upper and lower imposed limits thereon." (Office action, page 4). Notwithstanding the Examiner's remarks, applicants submit that the Cope reference fails to teach or suggest each and every aspect of the invention as claimed.

The present invention advantageously controls the diameter of a single crystal silicon ingot being pulled from a semiconductor source melt according to a stored velocity profile. Those skilled in the art recognize that the conventional control methods require varying the pull rate in response to diameter error because temperature dependent methods are too slow in responding. The cited art, however, fails to address this problem and merely discloses a conventional method for controlling silicon crystal growth that requires independent closed loop control of each of melt temperature, melt level, and diameter. (See Cope, col. 4, lines 50-56). Moreover, the Cope reference clearly teaches away from the present invention in that the Cope "diameter control algorithm 82 . . . is coupled to supply a set point signal to pull motor controller 65," which controls the crystal pull motor 65. (Cope, col. 5, lines 2-5).

In contrast to Cope, the present invention relates to an improved method for controlling silicon crystal diameter in a ***locked*** seed growth process. A velocity profile stored in a memory defines a target pull rate. Because the velocity profile is predetermined, it is unnecessary to adjust the pull rate in response to changing process conditions (i.e., diameter). Applicants have defined relationships between diameter variations and melt temperature and between melt temperature and heater power to achieve diameter control. (See application, page 21). In particular, applicants beneficially obtain a proportional-integral-derivative (PID) of an error signal representative of the difference between the crystal diameter set point and the crystal diameter process variable. The PID produces a ***temperature*** set point that is compared with a ***temperature model*** and a corresponding power set point is determined. The power supplied to the heater is then adjusted in accordance with the power set point to effect desired changes in the crystal diameter. The present application describes how the temperature model 273 estimates the relationship between heater power and the temperature of the surface of silicon melt 29. In one embodiment, temperature model 273 provides a model of the rate of diameter change. Although

controlling crystal diameter by controlling the melt temperature may not be as robust as controlling by pull rate, control loop 261 advantageously provides the benefits of a locked seed lift process with faster, accurate diameter control. (See application, page 20, line 17 to page 21, line 2).

To this end, independent claim 1 recites a method for controlling silicon crystal growth in which an ingot is pulled from the melt at a target rate that substantially follows a predetermined velocity profile in combination with "defining a temperature model representative of variations in the temperature of the melt in response to variations in power supplied to a heater for heating the melt." PID control is then performed on a generated signal that is representative of an error between the target diameter and the measured diameter to determine a temperature set point. Further, claim 1 recites "determining a power set point for the power supplied to the heater from the temperature model as a function of the temperature set point generated by the PID control."

As mentioned above, the Examiner asserts that maintaining the crystal pull rate specified by the diameter control algorithm reads on pulling at a target rate which substantially follows a set velocity profile. However, pulling at a locked target rate in accordance with velocity profile stored in a memory is markedly distinguishable from adjusting the pull rate in response to diameter feedback. The former simplifies control by reducing the number of processing parameters that are affected by current processing conditions and the latter complicates control by introducing a parameter that is both affected by current processing conditions and affects current processing conditions. For example, pulling the crystal according to a predetermined velocity profile, or target, specified in a crystal "recipe" (i.e., memory) helps satisfy process needs for controlling the formation of defects. (See application, page 14).

Nothing in the Cope reference teaches or suggests pulling a crystal at a locked pull rate in accordance with a predetermined velocity profile in combination with adjusting heater power to affect diameter changes. As discussed above, the prior art teaches away from such control because the delay in effecting melt temperature changes is thought to be unacceptable for diameter control. Advantageously, the present invention, as recited in claim 1, employs "a temperature model representative of variations in the temperature of the melt in response to variations in power supplied to a heater for heating the melt." This enables accurate diameter

control using only heater power and eliminating the pull rate variability required by Cope to control diameter.

For these reasons, applicants submit that claim 1 is allowable over the Cope reference. Claims 2-10 depend from claim 1 and are believed to be allowable for at least the same reasons as claim 1.

Moreover, applicants submit that the Cope and Araki references, whether considered separately or together, do not teach or suggest the method of claims 2-10 in which corrective adjustments to heater power, and not pull rate, are determined as a function of diameter variations. As described above, the Cope patent teaches away from applicants' claimed invention and does not suggest controlling temperature according to a temperature model to control crystal diameter. One of ordinary skill in the art would not have found it obvious to modify the teachings of the Cope patent, alone or in view of Araki, to meet the limitations of applicants' claims 2-10.

In view of the foregoing, applicants submit that claims 1-10 are now in condition for allowance and respectfully request favorable reconsideration of this application.

Applicants have reviewed the cited art not relied upon by the Examiner and have found it to be no more pertinent than the art discussed herein.

The Commissioner is hereby authorized to charge any fees that may be required during the entire pendency of this application to Deposit Account No. 19-1345.

Respectfully submitted,

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VERSION WITH MARKINGS SHOWING CHANGES MADE

IN THE TITLE

The title of the application has been amended as follows:

METHOD [AND APPARATUS FOR] OF CONTROLLING DIAMETER OF A CRYSTAL IN A LOCKED SEED LIFT GROWTH PROCESS.

IN THE CLAIMS

The claims have been amended as follows:

2 (amended). The method of claim 1 wherein the step of adjusting the power includes applying a pulse of power to the heater, said power pulse having [a predetermined duration and] an amplitude greater than a steady state value corresponding directly to the temperature set point.

Claims 11-18 have been canceled.